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Radio Frequency (13.56 MHz) Energy Enhances Rewarming from Mild Hypothermia.

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The rate of warming after hypothermia depends on the method of rewarming. This study compared the effectiveness of radio frequency (RF) energy against hot (41° C) water immersion (HW) and an insulated cocoon (IC) for rewarming hypothermic men. Six men fasted overnight and were rewarmed for one hour after attaining a 0.5° C reduction in rectal temperature (Tre). Tre and esophageal temperature (Tes) were recorded every 5 minutes with non-metallic thermal probes. The baseline value for Tre and Tes just prior to rewarming was subtracted from each 5 minute Tre and Tes during rewarming to give ΔTre and ΔTes. The twelve ΔTes values were averaged for each individual and compared using ANOVA. The average ΔTes for RF (1.15±0.2° C/hr) was faster ($p<0.001$) than either IC (0.37±0.16° C/hr) or HW (0.18±0.09° C/hr). The present study shows the superiority of radio frequency energy for rewarming mildly hypothermic

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INTRODUCTION

The rate of warming after hypothermia depends on the method of rewarming. Hot water immersion is a standard method for actively rewarming hypothermic individuals. However, field use of such apparatus is restricted by portability and energy requirements. Recent advances in radio frequency (13.56 MHz) energy delivery systems offer great promise for rewarming individuals in the field. The present study used non-metallic rectal and esophageal thermal probes to evaluate rewarming of mildly hypothermic men using radio frequency, hot water immersion, and insulated cocoon.

METHODS

° Six healthy male subjects

° Temperature --

Esophageal: fiber optic probe, level of the heart, right atrium

Rectal: carbon teflon, 10 cm past anal sphincter

Skin: fiber optic: mid - back, triceps

° Blood -- 18 G catheter in antecubital vein for plasma catecholamines:

norepinephrine and epinephrine

° Rewarming devices:

Radio frequency coil system (Fig. 1)

- SAR 2.5 W/kg body weight

Hot (41 C) water immersion

Insulated cocoon

° Experimental protocol:

overnight fast

immersed to nipple level in cold (12 C) water

reduction of rectal temperature by 0.5 C

removed from cold water and rewarmed using three devices in cross - over design

subjects in seated up - right position for all conditions

each subject served as his own control

RESULTS

Cooling - cooling times not different between cold water immersions

Tes paralleled change in Tre

plasma norepinephrine increased 3 - fold after each cold water immersion (Fig. 2)

plasma epinephrine did not change

Rewarming - Tre continued to fall during the rewarming period for all conditions (Fig. 3)

Tes did not exhibit afterdrop as seen for Tre (Fig. 4)

average Tes for RF (1.15 +0.22 C/hr) was faster ($p<.001$) than either IC (0.37 + 0.16C/hr) or HW (0.18 + 0.09)

shivering and NE depended upon a summation of both skin and core temperature (table 1)

SUMMARY

1. The present study demonstrates the potential of radio frequency energy for rewarming the thoracic cavity of mildly hypothermic men.

2. Our results indicate that rewarming at 6.0° C/hr is feasible in humans at an RF dose of 10 W/kg body weight.

3. Areas outside of the RF coil field do not rewarm as rapidly as those areas within the field. Consequently, RF rewarming induces a large outward (core → periphery) thermal gradient, thereby reducing the likelihood of cold induced cardiac arrhythmias.

CONCLUSIONS

1. Helical coil radio frequency (13.56 MHz) energy is superior to and insulated cocoon and hot water immersion for rewarming the thoracic region.
2. This study provides evidence that radio frequency energy heats the thoracic region, which is a major benefit for field and air rescue units that must deal with hypothermic individuals.

ACKNOWLEDGMENTS

Research and Development Command work unit number 63706N.M0095.004.1008. The opinions or assertions expressed herein are the private ones of the authors and are not to be construed as official or reflecting the views of the Department of Defense, the Department of Navy, or the Naval Service at Large.

FIGURE LEGENDS

Figure 1. Radio frequency rewarming coil system and commercial frequency generator.

Figure 2. Average (n=4) plasma norepinephrine (ΔNE) levels during cold water immersion (±34 minutes) and one hour of rewarming. Methods were radio frequency (13.56 MHz) energy (+), hot (41° C) water immersion (o) and an insulated cocoon (Δ). The baseline (0) just prior to cold water immersion was subtracted from each subsequent value. The average ΔNE for the insulated cocoon was higher ($p<0.02$) than for hot water immersion.

Figure 3. The average (n=6) rectal temperature rewarming profile for radio frequency (13.56 MHz) energy (+), hot (41° C) water immersion (o), and an insulated cocoon (Δ). The baseline (0) just prior to rewarming was subtracted from each subsequent rewarming value to give ΔTre.

Figure 4. The average (n=6) esophageal temperature (ΔTes) rewarming profile for radio frequency (13.56 MHz) energy (+), hot (41° C) water immersion (o) and an insulated cocoon (Δ). The baseline (0) just prior to rewarming was subtracted from each subsequent rewarming value to give ΔTes.

TABLE LEGEND

Table 1. Average values for plasma norepinephrine (NE), esophageal temperature change (Tes), average thigh temperature at the end of 60 minutes, and the shivering response.

FIGURE 1

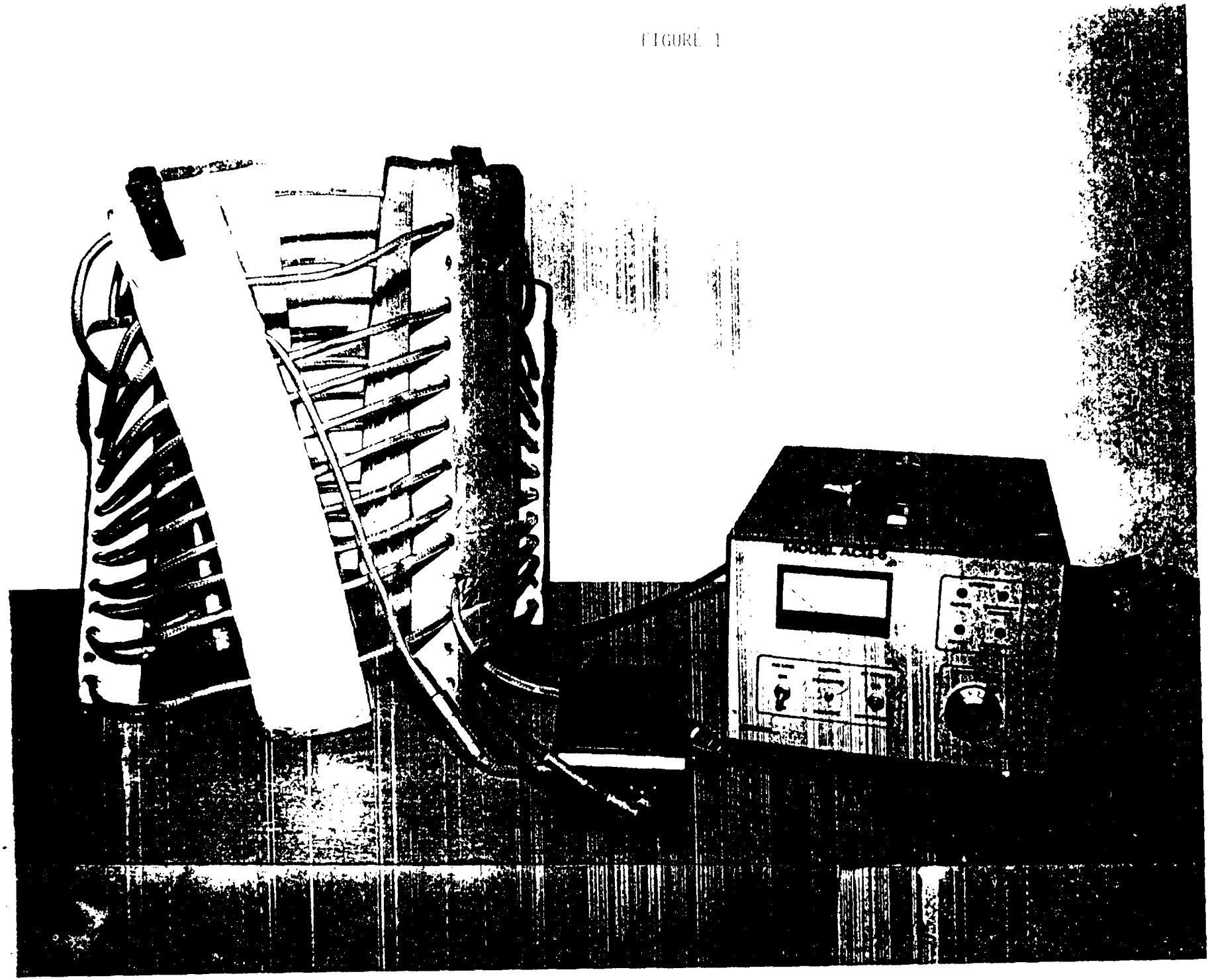

FIGURE 2

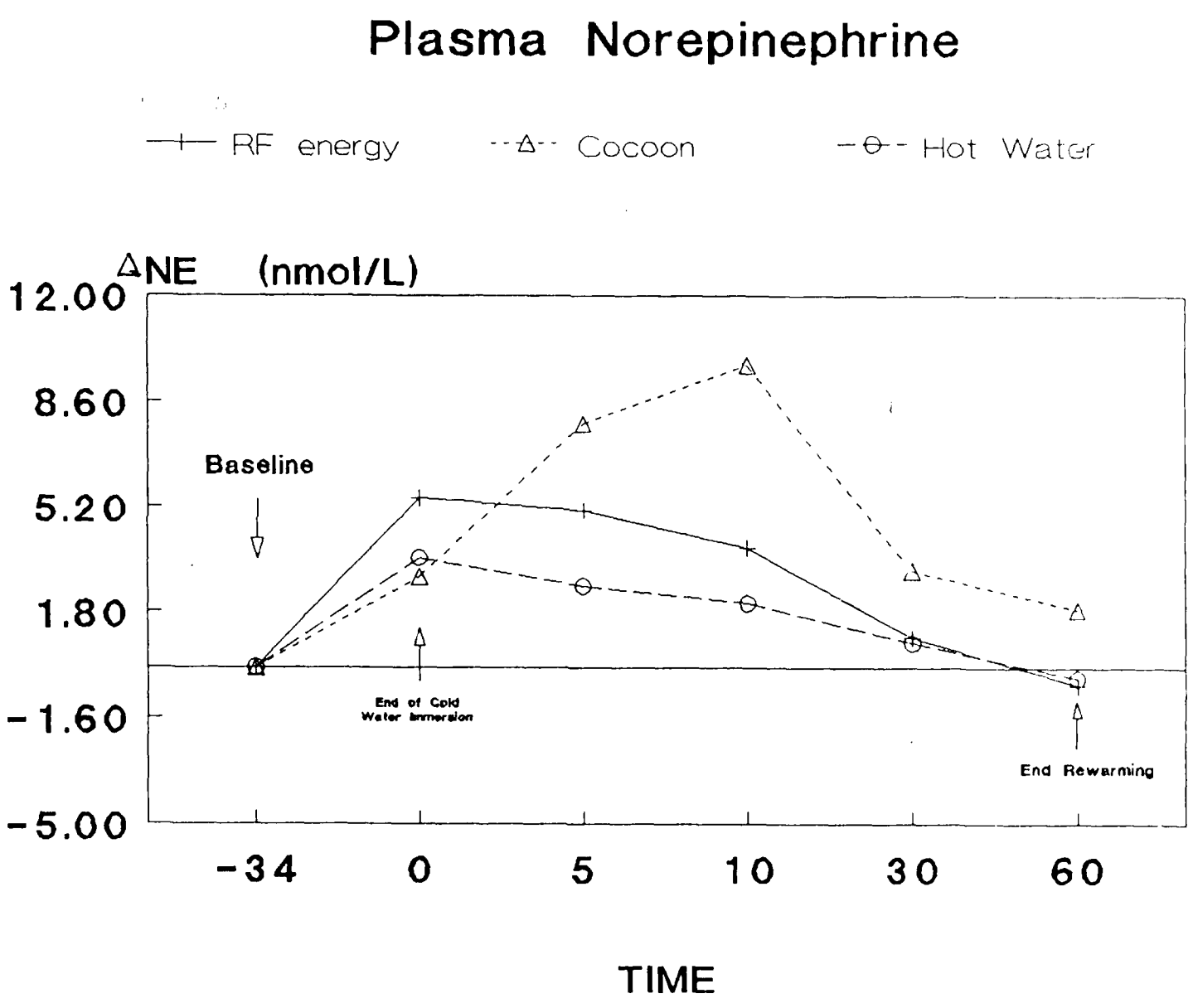
Plasma Norepinephrine
RF energy
Cocoon
Hot Water
ΔNE (nmol/L)
12.00
8.60
5.20
1.80
-1.60
-5.00
Baseline
End of Cold Water Immersion
End Rewarming
-34
0
5
10
30
60
TIME

FIGURE 3

Rectal Temperature

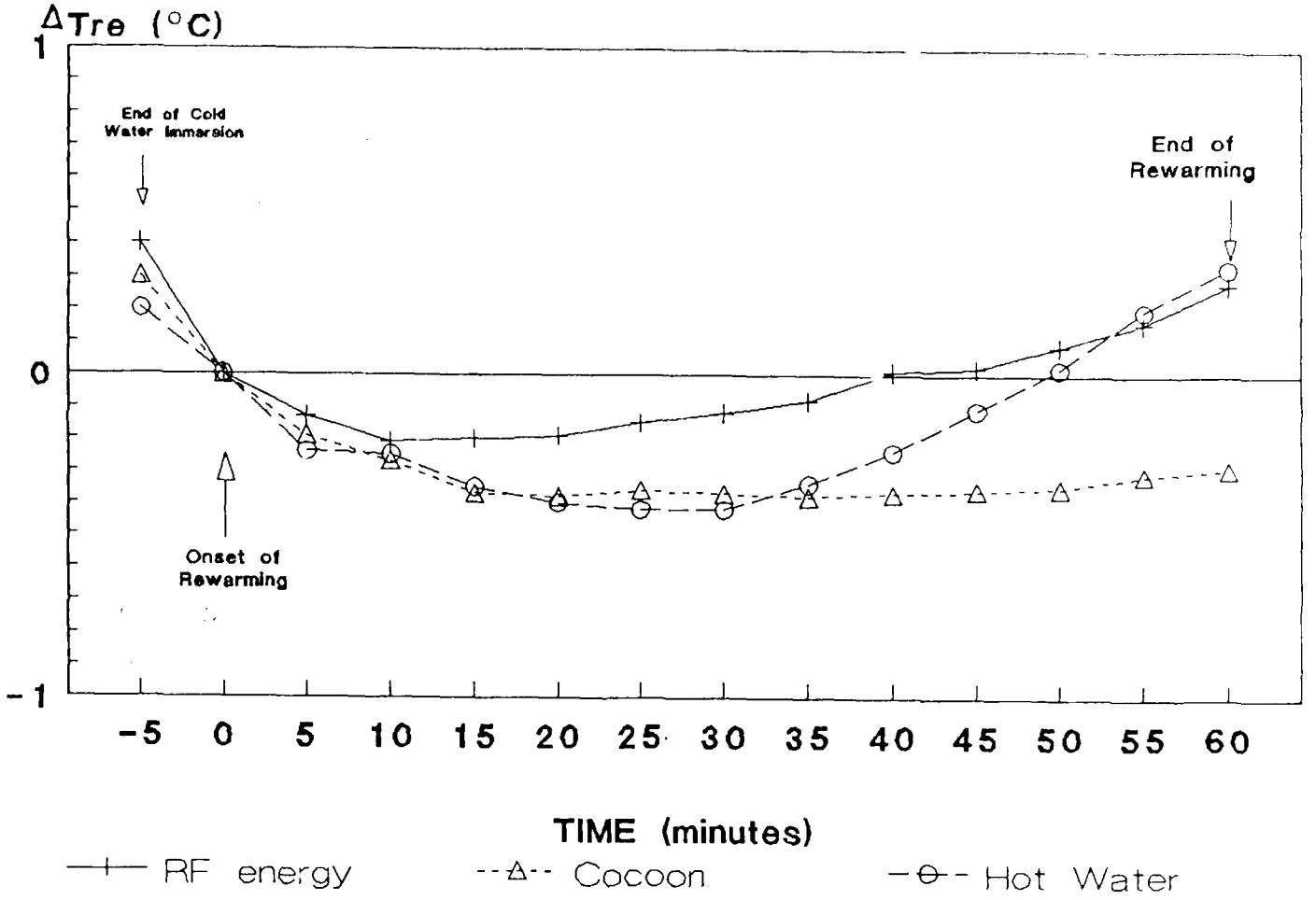

FIGURE 4

Esophageal Temperature

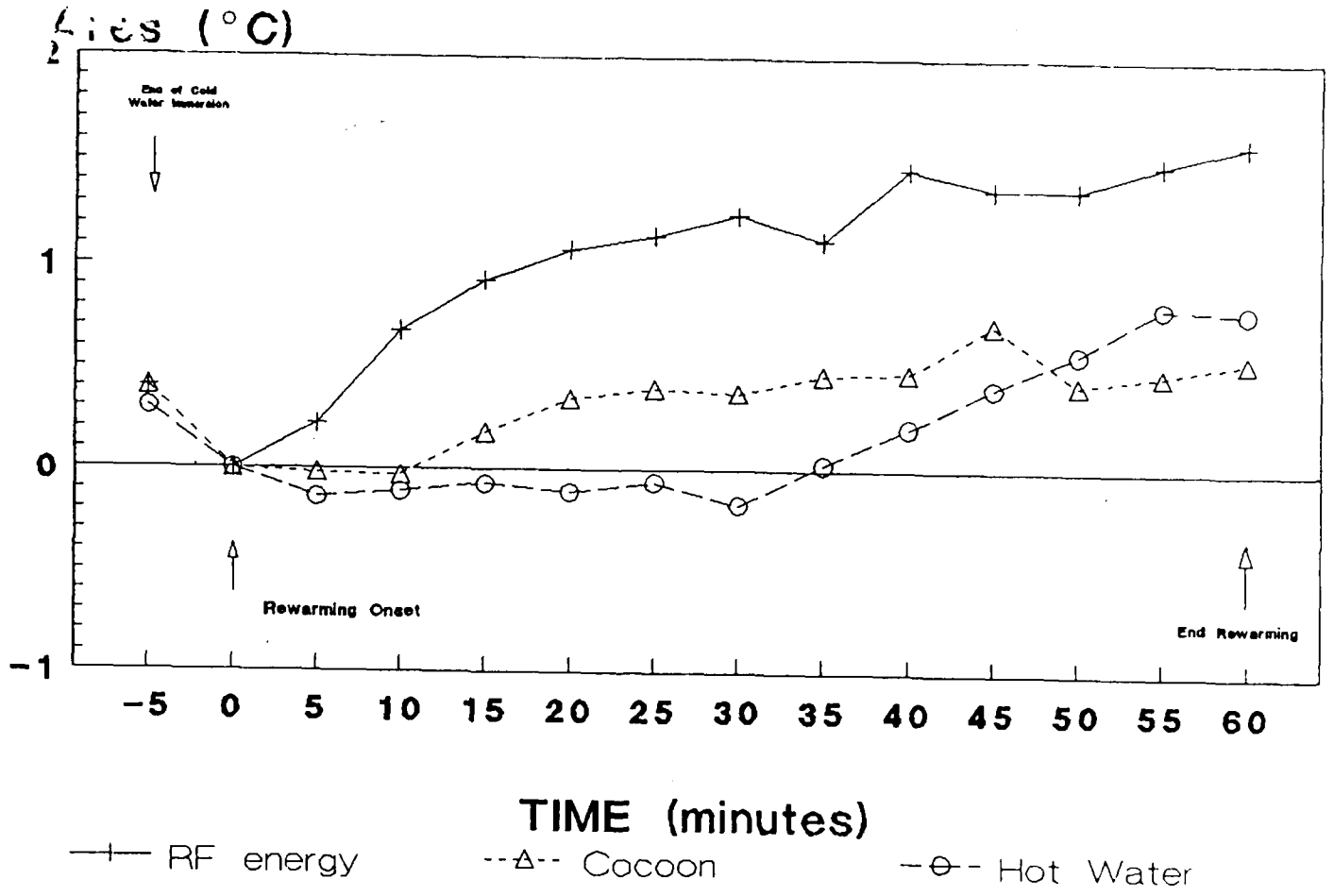

TABLE I

Variables	Average HS mmol/L	Average Rise °C/hour	Setting Point High (°C)	Above HLT Response
HW	1.29	0.18	38.0	—
RF	2.33	1.15	21.3	4
IC	5.67	0.37	26.9	14